ANALYSES OF REQUIREMENTS FOR COMPUTER CONTROL AND DATA PROCESSING EXPERIMENT SUBSYSTEMS

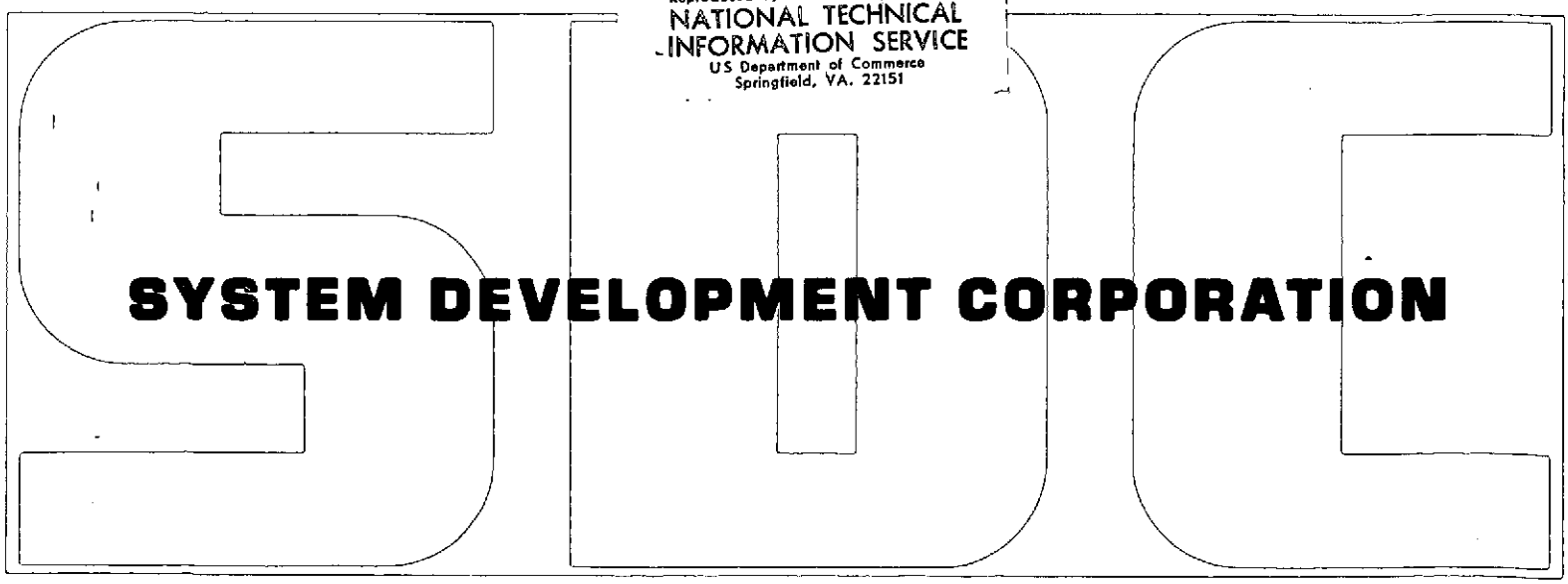
IMAGE DATA PROCESSING SYSTEM

IDAPS

USERS MANUAL (7094 VERSION)

VOLUME I

15 SEPTEMBER 1973



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TECHNICAL MEMORANDUM

(TM Series)

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ATM EXPERIMENT

S-056

IMAGE DATA PROCESSING SYSTEM

IDAPS

USERS MANUAL (7094 VERSION)

VOLUME I

15 SEPTEMBER 1973

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I

TABLE OF CONTENTS

LIST OF FIGURES

FOREWORD

This document was produced under NASA Contract Number NAS8-25471, "Analyses of Requirements for Computer Control and Data Processing Experiment Subsystems" by the System Development Corporation's (SDC) Huntsville Space Projects staff for the Computer Systems Division of the George C. Marshall Space Flight Center's Computation Laboratory. The work represented by this document was performed under the technical direction of Mr. Doug Thomas, Contracting Officer's Representative for the project. Appreciation is expressed to Mr. Thomas and to Mr. Bobby Hodges of the MSFC Computation Laboratory, and to Mr. J. E. Milligan of the Space Sciences Laboratory for their support and technical assistance during the course of this project.

During the development planning of the Solar Imaging X-ray Telescope (ATM Experiment S-056), it became evident that computer techniques for processing photographic data would be necessary in order to assure maximum effectiveness in utilizing the information obtained by the experiment. Because of the unique imaging characteristics of the telescope, and the volume of data that was expected (some 24,000 frames), it was decided that appropriate image processing techniques should be developed on a prototype basis and applied to exemplary data frames from the S-056 telescope before a commitment was made on a full scale processing system design.

During the period March 15, 1971 to March 15, 1972, System Development Corporation developed a prototype Image DAta Processing System (IDAPS) which incorporated many of the image processing techniques that would be required by the S-056 experiment into a single, rudimentary operating system. This first version of IDAPS was designed to run on an MSFC furnished 7094 Mod. I computer with magnetic tape bulk storage, and was documented in SDC TM-(L)-HU-033/006/00, "ATM Experiment S-056 Image Data Processing System Software Development - Volume II".

An IBM 1301 disk unit was installed on the 7094 computer and in March, 1972, SDC began developing an expanded version of IDAPS with improved systems capabilities

to take advantage of the disk storage and to expand the applications capabilities for processing S-056 image data. This volume is the result of that expanded IDAPS development effort. It is specifically intended as a users manual for those who desire to process S-056 image data on the 7094 computer, but because of the general purpose nature of most of the applications packages of the system, it may be used for general image enhancement, restoration, and analysis tasks.

One important objective in the development of IDAPS was to explore the possibilities of designing a system which will be responsive to the theoretician who desires to process S-056 image frames but who can not predict the exact sequence of image processing techniques that will yield the most satisfactory results. This objective demanded a system responsiveness that is not normally obtained from a 7094 computer, but by installing a special users language into the IDAPS system and by taking fullest advantage of the overlay and other systems features of the 7094 IBSYS operating system, the desired responsiveness was provided. The beginning user of IDAPS should require no more preparation than a careful reading of the remaining sections of this manual in order to obtain productive use of the IDAPS system.

SECTION 1.0 INTRODUCTION

IDAPS (Image DAta Processing System) is a computer based, user oriented language and control system for use in processing image data. It was designed to meet the requirements for restoring, enhancing, and analyzing X-ray photographic images returned by ATM experiment S-056. Although IDAPS was developed for the S-056 experiment, the capabilities of the system are general purpose in nature and are applicable to many other image processing applications.

IDAPS consists of an extensive library of image processing techniques and an image processing operating system. Each image processing technique is an independent software module or operator capable of being executed by itself or in series with other operators. The operating system provides the capability of executing long sequences of operators in series; performs all I/O functions; automatically adjusts the format of the image data as required by a particular operator; assigns file names; opens, closes and deletes files; maintains the file directory; generates a log of the executed job stream including timing information for each operator, and provides optional detailed instructions to the user as required.

Image processing techniques incorporated in IDAPS include capabilities for filtering, convolving, deconvolving, correlating, contouring, smoothing, gray scale altering, averaging, rotating, expanding, scaling, subsetting, etc. A total of 44 operators are available to the user for use in restoring, enhancing, or analyzing images. In addition, 22 operators are provided to assist the user in controlling the image processing sequence including image input and output, file handling, looping, etc.

SECTION 2.0 GLOSSARY OF TERMS

Column	- A one-dimensional vertical array of picture elements.
Complex File	- An interleaved data file containing alternating lines of real and imaginary numbers.
Dicomed Display	- An electro-photo display device used in the MSFC-7094 image processing facility for "quick look" of image data.
Display Tape	- An image file tape formatted for viewing on the Dicomed display tube.
File Name	- A unique identification label assigned to each image file used or produced by the IDAPS system.
Frame	- An image file.
Frequency Domain	- That frame of reference in which an array value corresponds to a spatial frequency -- is normally obtained from the Fourier transform of data in the spatial domain.
Gray Scale	- A value (0 - 63) assigned to a picture element to indicate its degree of gray-ness.
Image File	- (Disk or tape) A two-dimensional array of numbers representing the gray levels of points in a digitized picture.
Image	- A rectangular array of picture elements; an image file.
Interleaved Data	- Image data which is arranged so that lines of real/imaginary data or magnitude/phase alternate on an image file.
Line	- A one-dimensional horizontal array of picture elements.
Line and Column Coordinates	- A pair of integer numbers used to describe the location of a single picture element within a frame of data; the row and column numbers of a picture element.

Operator	- A single image processing technique or control process. It may be a subroutine or a collection of subroutines, called by an identifying name, which carries out a specific task.
Optronics PhotoRead/PhotoWrite	- An electro-optical device used for converting film data to digital data on magnetic tape and for converting magnetic tape image data back to film format by exposing photographic film in a light-tight container.
Picture Element	- The smallest unit of a digitized picture representing the average gray level of a single area sample of an image.
.Pixel	- A picture element.
Row	- A line.
Scanner	- Refers to the Optronics PhotoRead device.
Sense Switches	- A group of six switches located on the 7094 computer console used for user communication with the IDAPS system to control five distinct functions.
Size	- Normally refers to the number of picture elements in an array along a horizontal and vertical line and should not be confused with the physical dimensions of an image on film.
Spatial Domain	- That frame of reference in which a picture element may be related to some physical area in a picture.
Spatial Frequency	- Describes the rate of variation in the gray levels of a picture along a straight line -- normally expressed in cycles per frame.
Table	- A one-dimensional array of real or integer data used as input to the IDAPS system for use by an operator.

SECTION 3.0 SYSTEM USE

The present version of IDAPS, to which this document applies, was designed to take maximum advantage of the capabilities of the MSFC-7094 image processing facility. The facility consists of a 7094-Mod. I computer with 32K words of core, twelve tape drives, a 1301 disk drive and an on-line printer and cardreader. Volume printout of alpha-numeric data is obtained from a tape-to-tape interface with an IBM 1401 computer/1403 printer in an adjacent facility.

Temporary display of image data is provided on a Dicomed Model 31 display tube. This is a magnetic tape input device which reads image data from tape and writes it on a deformable plastic screen using a modulated electron beam. The display is erased by a heat lamp which is controlled by a front panel switch. The Dicomed display image is 5.6 inches x 5.6 inches in area and has a line and column resolution of 1024 data points and an intensity resolution of 64 gray levels. Image generation time is typically 100 seconds.

Permanent display of image data is obtained from an Optronics Photowriter. This device accepts image data, stored on magnetic tape, and exposes photographic film which is contained in a light-tight film cannister. The Photowriter can write with either a 12.5, 25, or 50 micron square spot and typically requires ten minutes to write a picture with the 25 micron setting.

Image input to the system and to the Dicomed display and Photowriter is on seven track magnetic tape, in a format of six-bit-byte strings where one record corresponds to an image line, and a file corresponds to an image frame. Conversion of film data to this format is accomplished in the MSFC-7094 image processing facility with an Optronics PhotoReader. The PhotoReader is a digital, scanning micro-densitometer which converts average film density values for a localized spot to gray scale values (64 levels) and stores the data on magnetic tape. The PhotoReader can scan with 12.5, 25, or 50 micron resolution and typically requires ten minutes to scan a 256 x 256 array at 12.5 microns.

3.1 OPERATOR CARD FORMAT

The user of IDAPS communicates with the system via cards. A fixed field format is used for specifying IDAPS operators. The general form is:

Col. 1	Col. 24	Col. 30	Col. 36		Col. 72
OPERATOR NAME	Par. #1	Par. #2	Par. #3	etc.	(FILE NAME(S))

3.1.1 OPERATOR NAME

The operator name begins in column 1. Because only the first three characters of each operator name are examined by the system, the user may abbreviate the operator name to three or more characters.

3.1.2 PARAMETERS

Six card columns are provided for each required parameter. The field for the first parameter is columns 19 - 24, for the second, columns 25 - 30, etc. Each parameter must be right justified in its respespective field; i.e., there may be no trailing blanks in the field.

Parameters are of three types:

- Integer values
- Real values
- Flags

Integer values consist of 1 - 6 decimal digits written without a decimal point. Real values consist of 1 - 5 decimal digits written with a decimal point. Flags are generally a single decimal integer used to specify a desired option.

A default parameter option is provided for many of the operators. If the field is left blank on the card, the system assumes the standard, or default, option.

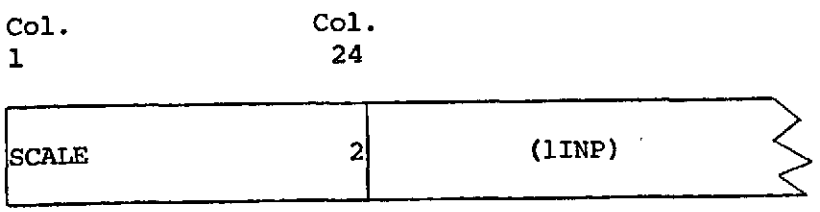
3.1.3 FILE NAMES

Each operator has available to it:

- One output file
- One to five input files

An operator's output file name is automatically defined, when an operator is encountered, as a constant (which represents the numerical order of its use) followed by the first three characters in the operator's name. For example, the first time the INPUT IMAGE operator is encountered, its output file is named 1INP. The next INPUT IMAGE operator encountered would create output file 2INP, and so on.

The automatic disk file assignment feature of IDAPS assumes that the input file for the current operator is the output file from the last previously executed operator that generated an output file. This automatic assignment may be overridden, however, if a non-standard input file is desired. The input file name is put on the operator card, enclosed in parentheses, following any specified parameters for that operator. Such file names may be placed in any column (4 - 72) except for those occupied by required parameters. For example:



For those operators that require more than one input file, the explicit designation of input files is mandatory. The input file names are placed on the operator card, enclosed in parentheses and separated by commas, as follows:

3.2 DATA CARD FORMAT

Some operators require data or tables to be input in addition to the parameters on the operator card. These are input immediately following their associated operator card. Table names begin in column 1 followed by an equal sign. Since the system does not check the name of the operator but simply looks for the equal sign, the actual name of the data set is unimportant and may be chosen at the user's discretion. A free form format is used for the data with values separated by commas. Multiple entries of the same value may be indicated by specifying the number of times the value is to be repeated, followed by an asterisk (*), followed by the desired value. For example, to repeat ten times the value 1, the following format is used:

```
...,10*1,...
```

The last value in the table must be followed by a dollar sign ($). Data may not extend beyond card column 78. If more than 1 card is necessary to input the desired data, a continuation card is used, indicated by a blank in column 1 with data resuming in column 2.

Data may be integer or floating point, depending on the requirements of the particular operator. Integer data is converted using an I18 format; thus each value may consist of from one to 18 digits.

Floating point data is converted using an F18.6 format; thus, a maximum of six digits to the right of the decimal point is allowed. The maximum number of characters, including decimal point, minus sign, etc., is 18.

The following examples demonstrate the data card format:

```
Col.
1
GROUP=8*1,8*2,8*3,8*4,8*5,8*6,8*7,8*8$
SEGMENTS=0.,1.,6.,16.,2.,1.,30.,0.,33.$
K=15*63,62,62,61,61,60,59,58,57,56,54,52,51,49,47,45,43,40,37,34,30,
 27,24,21,18,16,14,12,10,8,7,5,4,3,2,2,1,1,12*0$
MOD=0.,.0245,.09554,.206133,.3455,.5,.6545,.793867,.90446,.9755,1.$
```

Another type of data card that does not follow the above format is that of the label cards required by operators LABEL and MULTIPLE DISPLAY. (See the operator's descriptions in Section 4.0.)

3.3 IMAGE DATA FORMAT

Image data is stored and manipulated in both fixed point and floating point format. The internal format used by the system is determined by the requirements of each individual operator. Packed integer format is used most often because of its simplicity and compatibility with the scanner/display equipment. Floating point format is used where its extended accuracy is required.

An automatic conversion capability is included in IDAPS to convert an input file to the format required by a particular operator. Thus, the user does not have to keep track of the format of his files. There may be occasions, however, when it is desirable for the user to convert the data by use of a FIX or FLOAT operator, such as when a single file is used repeatedly and is in the wrong format for each use.

3.4 DISK FILES

The disk package developed for IDAPS is tailored to accomodate images. A digitized image is made up of n lines and m columns. Each of the n lines of the image is represented by one disk record m columns long. A record may take a fraction of a disk track (464 floating point words or 2784 packed 6-bit characters) or multiple tracks depending on the number of columns in the image and the format of the image. Thus, for a floating point file, size 1024 by 1024, each line (or record) occupies three tracks requiring a total of 3072 disk tracks to hold the image. A packed, integer format image, size 128 x 128, requires only 7 disk tracks to contain the image since 21 lines of data are stored on a track, with each line occupying 22 words of the track.

Files may be in one of three states: open, closed, or deleted. An open file has an assigned buffer equal in length to one disk track, enough disk space allocated to hold the file, and an entry in the file directory. A closed file does not have an assigned buffer but does have disk space allocated and an entry in the file

directory. A deleted file has no assigned buffer or file directory entry and may or may not have allocated space on the disk depending on how it was deleted. When a file is deleted, if it was the last file opened, disk space is released; however, no attempt is made to release disk space that is embedded between two other files.

The required input, output and scratch files are automatically opened, in that order, prior to operator execution. Upon completion of execution, input and output files are closed and all scratch files are deleted. Since the scratch files are deleted in the reverse order of their opening, disk space is thus released for later use.

The user may want to delete a generated file for one of the following reasons:

- He is running out of disk space. (There are a maximum of 20,000 tracks available.)
- He is approaching the limit of the file directory (100 files).
- He wants to reuse a file name (see REPEAT operator).

Files may be deleted by use of the DELETE FILES operator.

3.5 TAPE FILES

Tapes are used for image input and output and for operations which lend themselves to sequential access. The following tapes are used:

- A5 - Image and file input
- A6 - Image and file output
- B6 - Scratch tape for STACK and MULTIPLE DISPLAY operators and for file output
- B7 - Scratch tape for REPEAT operator

Those operators which require specific tape units and those which may be optional are noted under the individual operator's descriptions (Section 4.0).

3.6 SENSE SWITCH OPTIONS

The following sense switch options are available:

- Sense Switch 2 - Break key
- Sense Switch 3 - Pre-run diagnostics
- Sense Switch 4 - Operation mode
- Sense Switch 5 - Timing
- Sense Switch 6 - Disk file directory printout

3.6.1 SENSE SWITCH 2 - BREAK KEY

The Break Key is designed to allow the user to terminate an executing operator. Upon depression of sense switch 2, the system reacts as follows:

1) The executing operator is terminated.
2) All files are closed or deleted in the same manner as for the normal completion of the operator's execution.
3) A message is printed on the on-line printer.
4) A pause occurs so the user may change his operator card or skip the operator before resetting the sense switch and resuming execution.

3.6.2 SENSE SWITCH 3 - PRE-RUN DIAGNOSTICS

The pre-run diagnostic option (sense switch 3 down) allows the user to take advantage of the system's diagnostic package to preview his entire series of operator cards for possible errors or omissions before actually executing the series. Following the pre-run diagnostic scan the user must replace the cards in the card reader to execute them.

Options are as follows:

- Sense switch 3 down - Pre-run diagnostics
- Sense switch 3 up - Normal execution

3.6.3 SENSE SWITCH 4 - OPERATION MODE

Two modes of operation are available to the user:

- Step-by-step mode
- ZIP mode

In the step-by-step mode, explicit instructions are printed for the user and automatic pauses occur to allow the user to perform such tasks as tape loading. In the ZIP mode of operation, only minimal instructions are printed and no pauses occur. The primary advantage of the ZIP mode is that it allows the user to specify long and complex sequences to be run with a minimum of user participation.

Options are as follows:

- Sense switch 4 down - ZIP mode
- Sense switch 4 up - Step-by-step mode

3.6.4 SENSE SWITCH 5 - TIMING

The user may choose to have the execution time printed for each operator. Sense switch options are:

- Sense switch 5 down - Timing
- Sense switch 5 up - No timing

The computer's internal clock must be turned on to use this option.

3.6.5 SENSE SWITCH 6 - DISK FILE DIRECTORY PRINTOUT

This option was designed primarily for debugging the disk package but was found useful for detecting errors in the user's job sequence; therefore, it was left in the system.

The file directory consists of the following entries for each file:

1) File identification
2) Number of lines per image
3) Number of columns per line

4) Starting track number
5) Number of lines per track
6) Number of tracks
7) Data type (packed integer or floating point)
8) Buffer index
9) Disk unit assigned

In addition to the above information maintained for each file, the following general information is maintained:

1) Number of assigned files
2) Number of open buffers
3) Last track used on each of the two disk units

All of the above parameters are printed for each file opened, reopened, or closed.

3.7 SYSTEM LOADING

An up-to-date compilation of IDAPS is maintained by the System Development Corporation on a B5 FAST TAPE. With a control card deck, the user may load IDAPS and proceed with the execution of his sequence of operators.

Figure 1 illustrates the deck set-up for calling IDAPS from the FAST TAPE library. This deck and the FAST TAPE are available at the computer facility for those who wish to use IDAPS.

Once the FAST TAPE card deck is set up, operation under IDAPS proceeds as follows:

1) Mount, load, and ready scratch tapes on drives A3, A4, B2, B3, and B4, and system print tape on B1.
2) Mount, load, and ready the IBSYS system tape on A1, and the IBSYS FAST TAPE on B5.
3) Clear and reset the computer.
4) Clear the card reader.
5) Place sense switch 1 down, all others up.
6) Load the FAST TAPE card deck and press the card reader START to initialize.

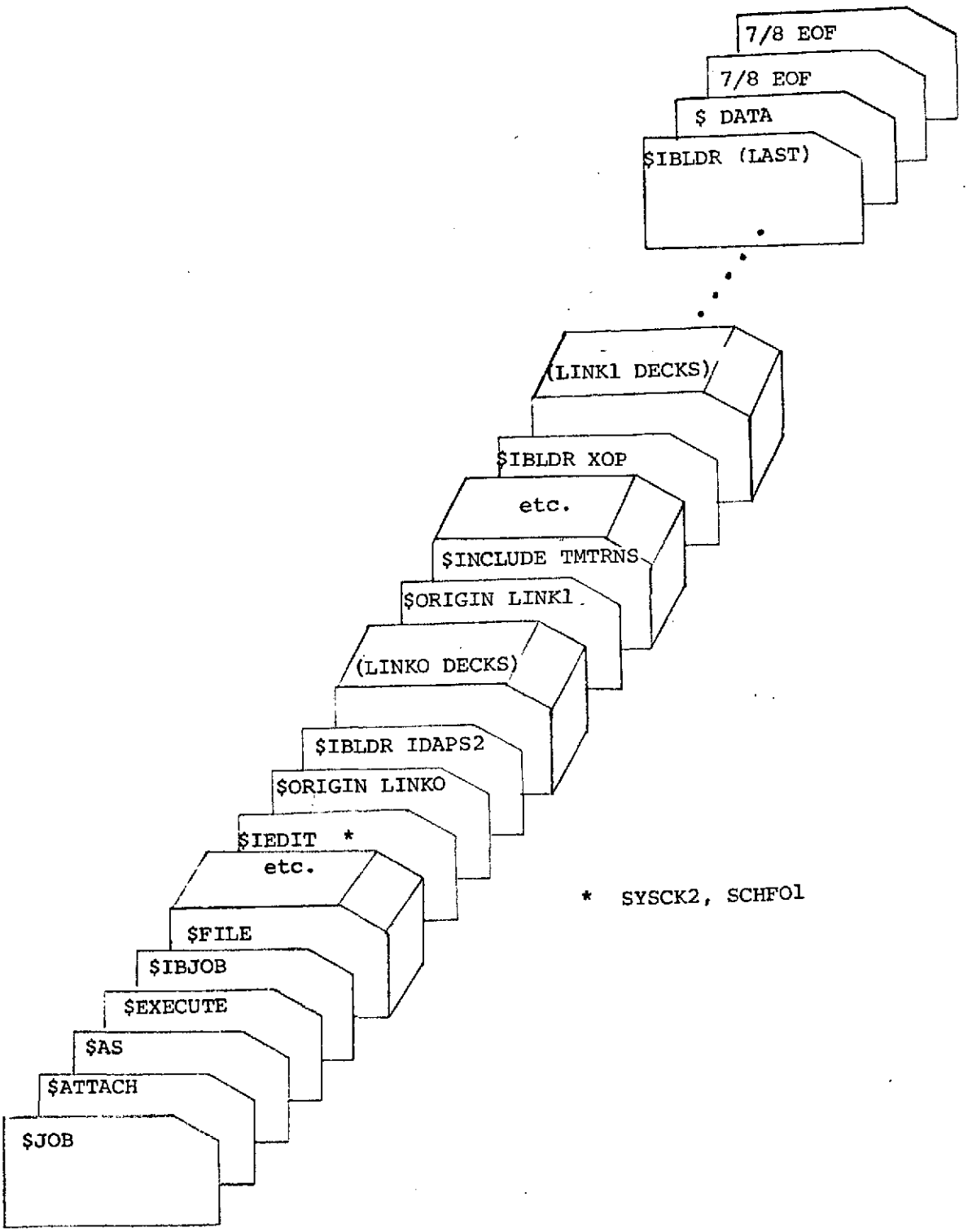


Figure 1 - Deck Set-Up for FAST TAPE Operation

7) Press LOAD TAPE.

8) After IDAPS is compiled and loaded, place sense switch 1 up and follow the instructions printed on the on-line printer.

SECTION 4.0 IDAPS OPERATORS

For the convenience of the user, operators are listed in this section in alphabetic order.

HISTOGRAM Operator

HORIZONTAL ROTATE Operator

IFFT Operator

INCLUSIVE OR Operator

INPUT IMAGE Operator

INSERT Operator

ISOGRAM Operator

LABEL Operator

LOAD FILE Operator

MATH Operator

MERGE Operator

MINOR TRANSPOSE Operator

MOMENT Operator

M/P TO R/I Operator

MTF Operator

MULTIPLE DISPLAY Operator

NON-SYMMETRICAL PSF Operator

OUTPUT IMAGE Operator

PAUSE Operator

PRINT Operator

PSF GENERATOR Operator

REINITIALIZE Operator

REPEAT Operator

RESTORE Operator

REWIND Operator

R/I TO M/P Operator

SCALE Operator

SHRINK Operator

SIZE Operator

SLICE Operator

SMOOTH Operator

SPLIT Operator

STACK Operator

STOP Operator

SUBSET Operator

TRANSPOSE Operator

VERTICAL ROTATE Operator

+90 DEGREE ROTATE Operator

The +90 DEGREE ROTATE operator rotates a frame of data 90 degrees in a clockwise direction. For example, an F would appear as ⅁.

Col.
1

Output data type:

Integer or floating point (same as input)

Subroutines:

TRNPS

TRANS

DRIVTP

FLIP

180 DEGREE ROTATE Operator

The 180 DEGREE ROTATE operator rotates a frame of data 180 degrees. For example, an F would appear as ⅁.

Col.
1

Output data type:

Integer or floating point (same as input)

Subroutines:

TRNPS

DRIVTP

FLIP

-90 DEGREE ROTATE Operator

The -90 DEGREE ROTATE operator rotates a frame of data -90 (or 270) degrees. For example, an F would appear as ⊔.

Col.
1

Output data type:

Integer or floating point (same as input)

Subroutines:

TRNPS

TRANS

DRIVTP

ALTER Operator

The ALTER operator changes the gray scale value of each picture element in a frame of data, using the original gray scale value from the input frame as an index to a table of values supplied by the user to determine the altered value.

Col.
1

The table of alteration values (table K) is input immediately following the ALTER operator as follows:

Col.
1

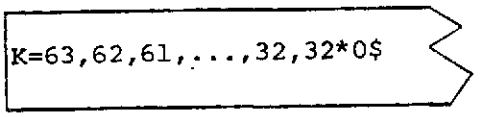


Table K is 64 values long and is ordered from gray scale 0 to gray scale 63, i.e., the value in the first position of table K will replace all original pixels whose gray scale value is 0, etc.

Output data type:

Integer

Subroutines:

SHADE

AND Operator

The AND operator performs a logical intersection of two frames of data on a bit-by-bit basis.

For example:

Bit positions of Pixels	1	2	3	4	5	6
Pixel from Input File #1	0	0	1	1	0	1
Pixel from Input File #2	0	1	1	0	1	1
Output Pixel from AND Operation	0	0	1	0	0	1

Col.
1

```
AND          (INPUT FILE NAMES)
```

Output data type:

Integer

Subroutines:

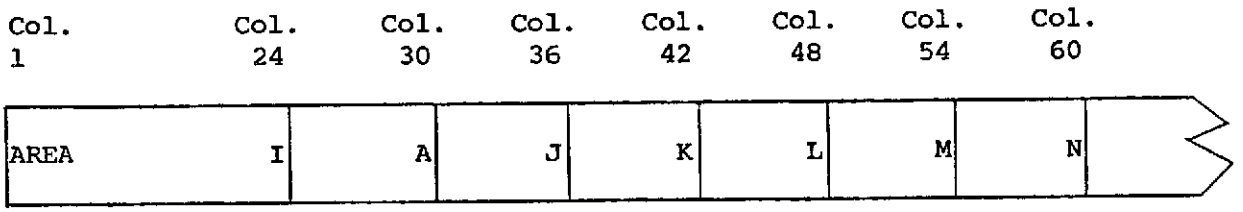
ØRAND

Restrictions:

1) Two input file names must be specified in parentheses.

AREA Operator

The AREA operator applies specifically to photographs taken by the S-056 telescope of the sun and is intended to calculate the total area of specific features on the solar disk. Before applying the AREA operator, the user must first isolate a specific feature from the rest of the solar photograph. This may be done by applying the SUBSET operator and then identifying the subset number assigned to the feature of interest. That subset number is then inserted as the (I) parameter of AREA. The aspect ratio of the feature is accounted for as a function of the distance of each pixel within the feature from the center of the disk.



I - The picture element value which identifies the solar feature for which the area is calculated.

A - Size of the scanning aperture used, in microns (10^{-6} meters).

J and K - The line and column coordinates of the center of the solar disk with respect to the upper left corner of an original data frame. J and K might each have a negative value. (This assumes that the input array for AREA has been extracted from some larger picture array.)

L and M - Line and column coordinates of the upper left corner of the data frame being processed, with respect to the upper left corner of the larger data frame from which the input array for AREA was extracted. If the input array for AREA was not extracted from some larger array, then L = M = 1 and J and K above are simply related to the upper left corner of the input array.

N - Tag which indicates the aspect correction desired.

N = 0 - No aspect corrections

N = 1 - Correction based on a user supplied table of values

N = Other - Corrections based on internal table

If an aspect ratio table is to be supplied by the user (N = 1), it is input immediately following the AREA operator card as follows:

Col.
1

```
TABLE=1.,1.0002.1,0004,1.0008,.....,5.0225$
```

The length of the table must be 120 values.

Subroutines:

AREAC

AVERAGE Operator

The AVERAGE operator averages together the corresponding picture elements of N frames of data and produces a picture which is the average composite of all N frames.

Col. 1	Col. 24	
AVERAGE	N	(INPUT FILE NAMES)

N - Number of frames to be averaged.

Output data type:

Integer

Subroutines:

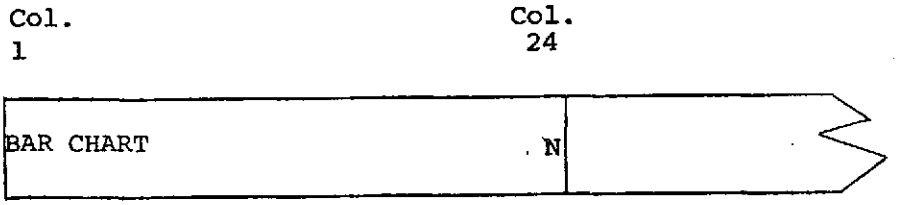
MLTAVS

Restrictions:

1) Input file names must be specified in parentheses.
2) A maximum of 6 frames may be averaged.
3) All input frames must be the same size.

BAR CHART Operator

The BAR CHART operator generates a chart of vertical black and white bars beginning at the top with a spatial frequency (left to right) of one cycle per frame and increasing in powers of two to 1/2 N cycles per frame at the bottom.



N - Size of the square bar chart.

Output data type:

Integer

Subroutines:

RSLGEN

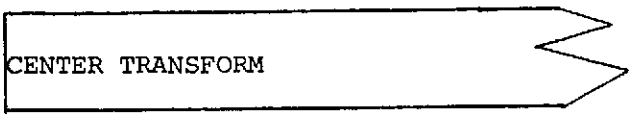
Restrictions:

1) The size of the bar chart must be a power of 2 less than or equal to 2048.

CENTER TRANSFORM Operator

The CENTER TRANSFORM operator multiplies each pixel by $(-1)^{i+j}$ where i is the line location and j is the column location of the pixel. This has the effect of causing the Fourier transform of the frame of data to be centered such that the d.c. term is located at the center of the transformed array rather than in the upper left hand corner.

Col.
1



Output data type:

Floating point

Subroutines:

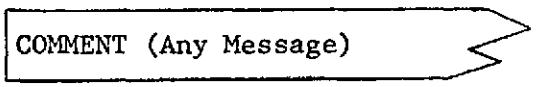
CENTR

Note: To center a frame of data, the CENTER TRANSFORM operator is applied before the FFT operator. To restore a picture from a centered transform, the CENTER TRANSFORM is applied after the IFFT operator.

COMMENT Operator

The COMMENT operator provides instruction or identification messages on both the on-line and off-line printers.

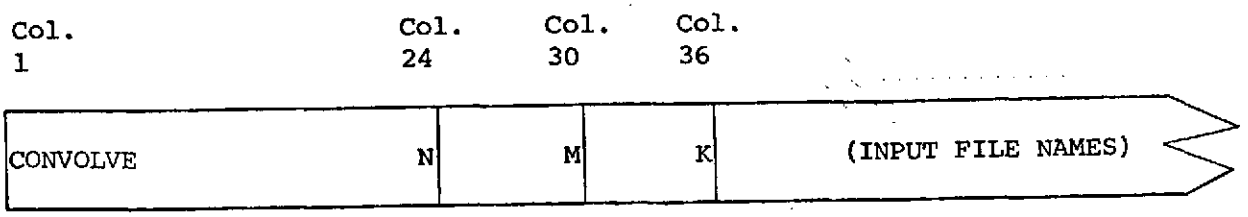
Col.
1



Columns 1 through 72 (including the operator name, COMMENT) are printed.

CONVOLVE Operator

The CONVOLVE operator convolves one two dimensional input function with a second two dimensional input function using a Fast Fourier Transform technique.



N - Size of the second input function. If the second input function is smaller than the first, it will be buffered up with surrounding zeros to equal the size of the first.

M - Size of the convolved image. If the parameter M is larger than the size of the input function, both input functions will be buffered up with surrounding zeros to equal M before being convolved.

K - Flag to indicate whether the second input function is to be input in the spatial or frequency domain.

K ≠ 1 - Spatial

K = 1 - Frequency (See Restriction 4)

Output data type:

Floating point

Subroutines:

CONV

FRX2V

FRXFM

SPRED1

Restrictions:

1) Two input file names must be specified in parentheses - image first, PSF second.

2) The input image frame must be a square array whose dimensions are a power of two.
3) The output convolved image must be a square array whose dimensions are a power of two, as designated by parameter M.
4) If the second input function is input in the frequency domain, it must be the same size as the first function.

CORRELATE Operator

The CORRELATE operator correlates two frames of data.

Col. 1	Col. 24
CORRELATE	N (INPUT FILE #1 NAME, INPUT FILE #2 NAME)

N - Size of the correlated output array. If N is larger than SIZE, both input frames are buffered up with surrounding zeros to equal N. (See Restriction 3.)

Output data type:

Floating point

Subroutines:

CRLATE

FRX2V

FRXFM

SPRED3

Restrictions:

1) Two input file names must be specified in parentheses.

2) Input frames must be square arrays whose dimensions are a power of 2.

3) The parameter (N) must be a power of 2.

DECONVOLVE Operator

The DECONVOLVE operator employs the Fast Fourier Transform (FFT) to deconvolve a frame of data with a point spread function (PSF). It divides frequency terms of the PSF into corresponding image frequency terms and then takes the inverse transform.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	Col. 48	
DECONVOLVE	N	M	K	J	L	(IMAGE FILE NAME, PSF FILE NAME)

N - Size of the PSF.

M - Size of the resulting deconvolved image.

K - Flag to indicate whether the PSF is input in the spatial or frequency domain.

K ≠ 1 - Spatial

K = 1 - Frequency

J - Limit on magnitude amplification.

J = Blank - No limit*

J = 0 - Allow no magnitude amplification

J = Other - Limit amplification to a maximum of J.

L - Limit on phase amplification, specified in degrees.

L = Blank - No phase limit

L = 0 - Allow no phase amplification

L = Other - Limit phase change to a maximum of L.

$-180° < L < +180°$

Output data type:

Floating point

* When the magnitude of a point of the PSF transform is zero, the corresponding point of the image transform is unaltered.

Subroutines:

DCONV

FRX2V

FRXFM

SPRED2

Restrictions:

1) Two input file names must be specified in parentheses.

2) The size of the deconvolved image must be a power of 2 equal to or greater than the size of the input image.

3) The size of the PSF must be equal to or less than the size of the input image.

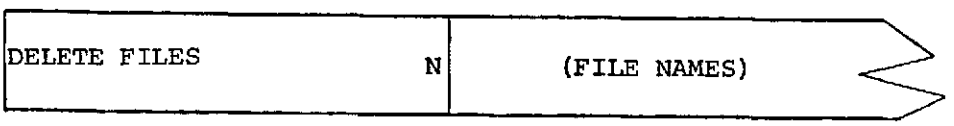
4) The input image, output image, and PSF must be square arrays.

DELETE FILES Operator

The DELETE FILES operator deletes specified files from the file directory. Its intended use is for:

- Deleting file names
- Deleting files from the file directory where there is danger of exceeding the 100 file maximum
- Freeing up disk space

Col. 1 Col. 24



N - Number of files to be deleted, where $1 \leq N \leq 9$.

Subroutines:

DELCLS

Restrictions:

1) N file names must be specified in parentheses.

2) N must be 9 or less. (Multiple DELETE FILES cards may be used if more than 9 files are to be deleted.)

3) Files are automatically deleted in the reverse order in which they are specified; e.g., if three DECONVOLVE operators have generated files 1DEC, 2DEC, and 3DEC, and are deleted as:

DELETE FILES 3 (1DEC, 2DEC, 3DEC)

file 3DEC will be deleted first, 2DEC second, etc. This will delete the three files from the file directory, reduce the total number of files in the directory, and free up the disk space used by the three files.

If the files were specified in the reverse order, ie.

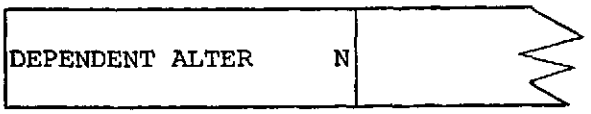
DELETE FILES 3 (3DEC, 2DEC, 1DEC)

then the three files would be deleted from the file directory, and the total number of files would be reduced by three but the disk space would not be freed because the disk handling software will only free up disk space from the last file in the file directory.

DEPENDENT ALTER Operator

The DEPENDENT ALTER operator performs a position dependent alteration of the gray scale value of each pixel.

Col. 1 Col. 24



N - Length of Tables A and B. The values of the A and B tables represent the coefficients of the linear expression A + BX, where X is the original pixel value. The index to the A and B tables is determined by the radial distance from the center of the frame to the pixel. Tables A and B are input immediately following the DEPENDENT ALTER operator. For example, if the picture is 512 x 512 and N = 362, the A and B tables may be input as follows:

```
Col.
1
A=362*0.$
B=250*1.,100*.5,10*.2,.1,.05$
```

Output data type:

Integer

Subroutines:

PDGSA

Restrictions:

1) N must be equal to or greater than one half the diagonal length of the picture to be processed, i.e.,

$$N \geq \sqrt{\left(\frac{L}{2}\right)^2 + \left(\frac{C}{2}\right)^2}$$

where L is the number of lines and C is the number of columns.

DISTANCE Operator

The DISTANCE operator is S-056 experiment specific and is intended to calculate the distance on the solar sphere between two points defined by spherical coordinates.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	
DISTANCE	A	B	C	D	

A - Latitude of point 1 (in degrees) $-180° < A \leq +180°$

B - Longitude of point 1 (in degrees) $-180° < B \leq +180°$

C - Latitude of point 2 (in degrees) $-180° < C \leq +180°$

D - Longitude of point 2 (in degrees) $-180° < D \leq +180°$

Subroutines:

DSTANC

DUMP FILE Operator

The DUMP FILE operator dumps a floating point disk file onto magnetic tape. The tape is not rewound so that additional files may be dumped onto the same tape.

Col. 1	Col. 24
DUMP FILE	N

N - Tape logical unit number which must be one of the following:

8 (A5)

10 (A6)

11 (B6)

Output data type:

Floating point

Subroutines:

DUMPF

EXPAND Operator

The EXPAND operator can be used to expand an area of a frame of data by some whole number factor.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	Col. 48
EXPAND	I	J	N	M	K

I and J - Upper left corner line and column numbers of the area to be expanded.

N and M - Number of lines and number of columns in the area to be expanded.

K - Expansion factor (positive integer).

Output data type:

Integer

Suborutines:

XPAND

EXTRACT Operator

The EXTRACT operator extracts a portion of a frame of data.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	
EXTRACT	I	J	N	M	

I and J - Upper left corner line and column numbers of the area to be extracted.

N and M - Number of lines and number of columns in the area to be extracted.

Output data type:

Integer

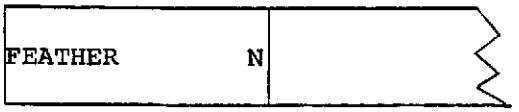
Subroutines:

XPAND

FEATHER Operator

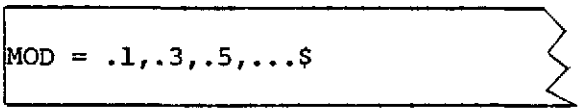
The FEATHER operator rounds off the edges of a frame of data by multiplying the pixels along the edges by appropriate factors input in table format.

Col. Col.
1 24



N - Size of the modification table which is input as follows:

Col.
1



The first value of MOD corresponds to the extreme edge of the frame of data to be feathered.

Output data type:

Integer

Subroutines:

SHAVE

Restrictions:

1) No more than 25 values may be listed for MOD.

FFT Operator

The FFT (Fast Fourier Transform) operator transforms an NxN frame of data to produce an MxM array of real and imaginary components in the frequency domain.

Col. 1	Col. 24	Col. 30
FFT	M	N

M - Size of the transformed array.

N - Normalization flag.

N = 1 - Normalize transform by dividing each term by the area under the input curve, and reversing the sign of alternate terms. This option is useful in creating fourier domain PSF filters for use with the DECONVOLVE operator where a number of input images are to be deconvolved with the same PSF.

N ≠ 1 - No normalization

Output data type:

Floating point (interleaved)

Subroutines:

XFORM

FRX2V

FRXFM

Note: The arrangement of the frequency terms produced by the FFT operator is typical of that produced by the Cooley-Tukey algorithm. The upper-left most term is the DC frequency component followed by frequency terms (as one moves from left to right, top to bottom) which correspond to the terms from the lower-right, lower-left, upper right, then upper left quadrants of an arrangement in which the DC term would be centered with increasing frequencies radiating outward from the center.

Because the FFT output file is an interleaved combination of the real and imaginary components of the transformed image, its size is 2 MxM elements. Operators M/P to R/I, R/I to M/P, SPLIT and IFFT are designed to handle this double length format without requiring a new SIZE specification. Other operators (such as PRINT) require a new size specification to operate on the output of FFT.

FIELD CORRECTION Operator

The FIELD CORRECTION operator corrects for gray scale distortion which are a non-uniform function of the location of a point within an image array. It assumes that, given a number (N) of different gray values, N arrays of gray values can be generated, to describe the distortions that occur within the field of view for each value.

Col. 1	Col. 24
FIELD CORRECTIONS	N

N - The number of correction planes (or tables), $3 \leq N \leq 8$.

The actual value of each correction plane is input following the operator card in table form as follows:

```
CURVE=5.,10.,20.,45.,60.$
```

Each value in CURVE represents the actual value of the gray scales of a correction plane. For example, if, as above, CURVE contains six values, then six correction planes must be generated. This may be accomplished by photographing 6 uniform fields of gray scale 5, 10, 20, ... as indicated. The digitized images resulting from photographing the uniform fields are the planes used for correction and are formatted on tape as follows:

RECORD 1	Line 1, Plane 1
RECORD 2	Line 1, Plane 2
.	.
.	.
.	.
RECORD N	Line 1, Plane N
RECORD N+1	Line 2, Plane 1
.	.
.	.
.	.
RECORD NL*N	Line NL,Plane N

The tape, with the correction planes properly formatted, must be generated prior to operation.

Method:

A three-point Lagrange interpolation is performed to find the corrected gray scale value for each pixel in the image. Assume the correction planes are designated X_1, X_2, ... X_n. The corrected value, $G(X_{ij})$ is then computed by interpolation as follows: Given the dependent variable table, $X_{1(ij)}$, $X_{2(ij)}$, ... $X_{n(ij)}$, as a function of the independent variable table, CURVE, find a value, $G(X_{ij})$, as a function of a given argument, X_{ij}.

Normal Tape Assignments:

A5 - Correction planes in interleaved format

Subroutines:

NSA

LAGRAN (IBSYS Library)

Restrictions:

1) $3 \leq N \leq 8$
2) Number of columns in image must be no greater than 1024.
3) Number of columns in correction planes must be equal to number of columns in image.

FILTER Operator

The FILTER operator applies a 3 x 3 moving window filter to an image by numerically convolving the input array with the 3 x 3 filter.

Col.
1

```
FILTER
```

The FILTER is input as follows:

```
FILTER = 4*-.125,2.0,4*-.125$
```

Output data type:

Floating point

Subroutine:

KONVL

Restrictions:

1) Nine values must be input for the filter.

FIX Operator

The FIX-operator converts a floating point file to fixed point.

Col.
1

Output data type:

Integer

• Subroutines:

FLTOFX

Restrictions:

1) The file should be scaled from 0. to 63. prior to using this operator; otherwise, values outside 0. to 63. will be truncated.

FLOAT Operator

The FLOAT operator converts a fixed point file to floating point.

Col.
1

Output data type:
Floating point

Subroutines:

FXTOFL

FOURIER FILTER Operator

The FOURIER FILTER operator applies a filter to an image in the frequency domain by multiplying each term of the transform by the corresponding term of the filter.

Col. 1	Col. 24	
FOURIER FILTER	N	(Image file name, Filter file name)

N - Input data format flag

N ≠ 1 - Input image in spatial domain format

N = 1 - Input image in frequency domain format (already transformed)

Output data type:

Floating point

Subroutines:

FFIL

FRX2V

FRXFM

Restrictions:

1) The sizes of the image and the filter must be powers of 2.
2) If N ≠ 1, the filter must be the same size as the image and the image and filter must be square.
3) If N = 1, the number of lines in the input image must be twice the number of columns, the filter must be square, and the size of the filter must be equal to the number of columns in the input image.

FRAME Operator

The FRAME operator produces a display tape containing a processed picture and the following information about it:

A gray scale step wedge
A histogram of gray scale distribution
Tic marks along the edges of the picture
Borders around the picture

Options available are:

Grid (user supplied increment or automatic)
Top and bottom labels
An arrow to point to an area of interest
Gray scale inverson

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	Col. 48	Col. 54	Col. 60	Col. 66
FRAME	I	J	K	L	M	KL	KC	N

I - Number of card images provided for the top label.

J - Number of card images provided for the bottom label.

K - Grid indicator.
If 0 or blank, then no grid is generated.
If 1, then an automatic 40 x 40 sector grid is overlaid.
If greater than 1, then K is the user supplied increment for the grid.

L - Gray scale inversion option indicator.
L = 1 - Picture is inverted .
L ≠ 1 - No inversion is performed .

M - Gray scale inversion option #2 indicator .
M = 1 - Output frame is inverted.
M ≠ 1 - No inversion is performed .

KL - Arrow option line coordinate for the arrow point .

KC - Arrow option column coordinate for the arrow point.

N - Arrow direction indicator. If an arrow is desired but no direction is given, the default is SW to NE unless the arrow won't fit in the frame.

N = 1 - SW to NE

N = 2 - SE to NW

N = 3 - NW to SE

N = 4 - NE to SW

After the FRAME card, the information required by the label options should occur in the following order:

(TOP LABEL CARD IMAGES)

(BOTTOM LABEL CARD IMAGES)

The labels applied to the frame are an exact image of the Label Card image. Therefore, no more than 72 characters can be placed on any one line of a label.

Output data type:

Integer (display format) on A6 tape unit

Subroutine:

FRAME

FRAMWR

HISTOW

ARROW

DSPLN

FUNCTION GENERATOR Operator

The FUNCTION GENERATOR operator produces a two-dimensional, symmetrical function based on the profile of a one-dimensional input curve.

Col. 1	Col. 24
FUNCTION GENERATOR	N

N - Input option.

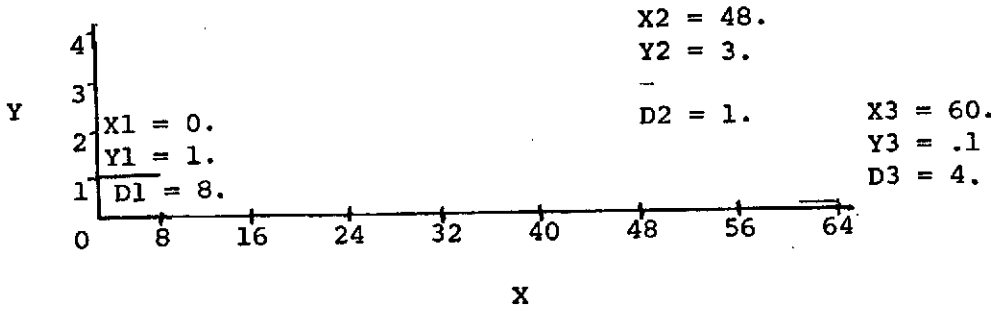
N = 1 - Input three horizontal line segments.

N ≠ 1 - Input curve profile.

erate the function from three line segments, input is in the following format:

Col. 1
SEGMENTS = X1, Y1, D1, X2, Y2, D2, X3, Y3, D3$

where (X,Y) defines the starting position of the line segment and D defines the length of the segment. For example:



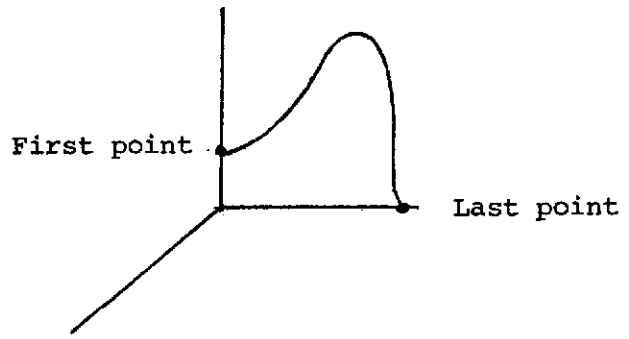
The line segments are joined by a cosine bell shaped curve. The resulting curve is rotated about the (0,0) point to produce a two-dimensional function.

To generate the function from a curve profile, input is in the following format:

Col.
1

```
CURVE = 1.0, 1.02, 1.05, 1.1, ... $
```

where the first value listed corresponds to the center position of the resulting rotated curve.



Subroutines:

FUNGN

Restrictions:

1) The number of values for the curve profile must be equal to 1/2 the size of the resulting two-dimensional function, e.g., if the two-dimensional function is to be 128 x 128, the number of values in CURVE must be 64. The number of values specified in SEGMENTS is always 9.

2) The resulting function is a square array and must be specified as such prior to generation.

3) To specify a point when using the line segment input option, input a length of 0.

HISTOGRAM Operator

The HISTOGRAM operator produces a histogram of the gray scale distribution of a frame of image data and calculates the following statistics:

sum of gray scale values
mean gray scale value
average deviation
variance
standard deviation
location of isolated maximum and minimum points

Col.
1

Subroutines:

STAT

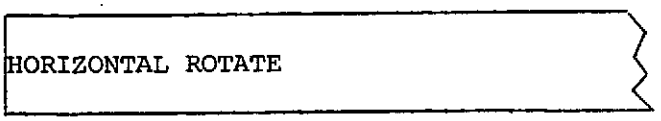
Restrictions:

1) Real data must be scaled from 0. to 63. before using the HISTOGRAM operator.

HORIZONTAL ROTATE Operator

The HORIZONTAL ROTATE operator flips a frame of data about a central horizontal axis so that line 1 becomes line n, line 2 becomes line (n-1), etc. For example, an F would appear as Ł .

Col.
1



Output data type:

Integer or floating point (same as input)

Subroutines:

TRNPS

DRIVTP

IFFT Operator

The IFFT (Inverse Fast Fourier Transform) operator converts an interleaved array of real and imaginary components in the frequency domain to an image array.

Col.
1

Input data type:

Floating point (interleaved)

Output data type:

Floating point

Subroutines:

IXFORM

FRX2V

FRXFM

INCLUSIVE OR Operator

The INCLUSIVE OR operator performs a logical union of two images on a bit-by-bit basis. For example:

Bit Position of Pixels	1	2	3	4	5	6
Pixel from Input File #1	0	0	1	1	0	0
Pixel from Input File #2	0	1	1	0	1	0
Output Pixel from Operator	0	1	1	1	1	0

Col.
1

```
INCLUSIVE OR      (INPUT FILE NAMES)
```

Output data type:

Integer

Subroutines:

ØRAND

Restrictions:

1) Two input file names must be specified in parentheses.

INPUT IMAGE Operator

The INPUT IMAGE operator transfers an image from tape to disk.

Col. 1	Col. 24	Col. 30	Col. 36
INPUT IMAGE	J	M	N

J - File number of image on tape.

M and N - Starting line and column numbers

Normal tape assignment:

A5 - Input

Input data type:

Integer (Scanner format)

Output data type:

Integer

Subroutines:

INIMAG

INSERT Operator

The INSERT operator inserts a sub-frame into any desired position in a larger major array.

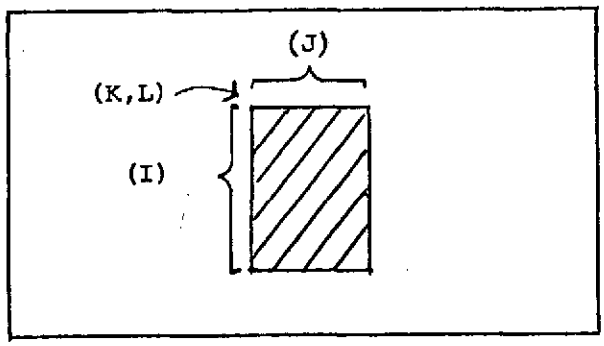
Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	Col. 48	
INSERT	I	J	K	L	M	(LARGE FILE NAME, INSERT FILE NAME)

I - Number of lines in array to be inserted.

J - Number of columns in array to be inserted.

K - Starting line location in major frame to insert sub-frame.

L - Starting column location in major frame to insert sub-frame.



M - Edge modification flag

M = 1 - Interpolate between edges to produce smooth transition

M = 2 - Enclose sub-frame in border

M = Other - No smoothing or border

Output data type:

Integer

Subroutines:

INSRT

Restrictions:

1) Input file names must be specified in parentheses - large array first, sub-array second,

2) When the edges are being smoothed (M = 1), the sub-frame must wholly fit within the large array with at least two rows and two columns additional on each side; i.e., K≥3, L≥3, etc.

3) When M ≠ 1, the sub-frame may not overlap the edges of the large array.

ISOGRAM Operator

The ISOGRAM operator produces a contour plot along the intersections of areas within an input frame which are above/below some specified thresholds. Since several different contour group thresholds may be specified, multiple contour plots may be produced in the output array.

Col. 1	Col. 24
ISOGRAM	I

I - Option to specify smoothing on each pixel of the input frame of data.

I = 1 - No smoothing

I ≠ 1 - Smoothing performed.

The contour group is input as follows:

Col. 1
GROUP=4*1,4*2,8*3,8*4,8*5,...$

The ith position of GROUP corresponds to the gray value in the input array and the number occupying the ith position is the contour group to which that gray value is assigned. In the above example, gray values 0, 1, 2, and 3 will be assigned to coutour group 1, gray values 4, 5, 6, and 7 to coutour group 2, etc. Contours will be plotted along the intersections of the various groups thus specified.

Output data type:

Integer

Subroutine:

ISOPLT

Restrictions:

1) 64 integer values must be entered for GROUP.

LABEL Operator

The LABEL operator inserts alphanumeric labels in a frame of data.

Col. 1	Col. 24	Col. 30	Col. 36
LABEL	N	M	I

N - Number of label cards which follow the LABEL operator.

M - Tape logical unit number where the frame of data will be input.

I - Output tape logical unit number

The format of the N label cards following the LABEL operator is:

Col. 6	Col. 12	Col. 18	Col. 25
J	K	L	(any desired label)

J - Number of characters in the label

K - Starting line position on the frame

L - Starting column position on the frame

The label image begins in card column 25 and continues for J columns. If the label is longer than 48 characters, it may be continued on a second card beginning in column 1.

Each character is output as a 9 x 7 matrix with a 9 x 3 matrix of trailing blanks; therefore, each character occupies 9 lines and 10 columns. Line spacing must be controlled by the user: a minimum of 5 lines between labels is recommended.

Input data type:

Integer (display format)

Output data type:

Integer (display format)

Subroutines:

LABL

DSPLIN

UNPAC

Restrictions:

1) The maximum number of characters per line (including spaces) is 102.
2) Column 72 is the last column of a label card that will be interpreted.
3) The starting line position specified on each successive label card must be greater than the line position specification of the previous label card.
4) All labels should be limited to the following character set: ABCDEFGHIJKLMNOPQRSTUVWXYZ1234567890+-(),/=.'*(space).
5) Tape units may be one of the following:
   8 (A5)
   10(A6)
   11(B6)
6) The size of the input image must be specified on a size card as follows:

Col. 1	Col. 24	Col. 30
SIZE	N	1024

where N is the number of lines in the input image. The input image must contain 1024 columns per line.

LOAD FILE Operator

The LOAD FILE operator loads a floating point tape file onto disk.

Col. 1	Col. 24	Col. 30
LOAD FILE	N	M

N - Tape logical unit number which must be one of the following:

8 (A5)

10 (A6)

11 (B6)

M - File number of desired file on tape N.

Output data type:

Floating point

Subroutines:

READF (Entry to DUMPF)

MATH Operator

The MATH operator performs the following point-by-point operations : A+B, A-B, A*B, A/B, A+C, A*C, C/A, AND A**C, where A and B are frames of data and C is a constant.

Col. 1	Col. 24	Col. 30	
MATH	K	C	(INPUT FILE NAMES)

K - Operation flag

K = 1 - A+B

K = 2 - A-B

K = 3 - A*B

K = 4 - A/B

K = 5 - A+C

K = 6 - A*C

K = 7 - C/A

K = 8 - A**C

C - a floating point constant to be used when K is greater than 4.

Output data type:

Floating point

Subroutines:

ARITH

UNPAC

Restrictions:

1) When K≤4, two input file names must be specified in parentheses - file A first, followed by file B.

MERGE Operator

The MERGE operator interleaves the complex components (real/imaginary or magnitude/phase) of two files line by line into a single file.

Col.
1

```
MERGE     (INPUT FILE NAMES)
```

Output data type:

Floating point

Subroutines:

MERG

Restrictions:

1) Two input file names must be specified in parentheses - real (or magnitude) first, imaginary (or phase) second.

MINOR TRANSPOSE Operator

The MINOR TRANSPOSE operator transposes a frame of data about the minor diagonal. For example, an F would appear as ⅃.

Col.
1

Output data type:

Integer or floating point (same as input)

Subroutines:

TRNPS

TRANS

DRIVTP

FLIP

MOMENT Operator

The MOMENT operator is intended for use with pictures of the sun taken with the S-056 experiment telescope. It calculates the apparent latitude and longitude (based on an assumed location of the solar equator and poles) of the centroid, the center of intensity, and the center of energy of a prespecified feature on the solar disk. Aspect distortion may be taken into account on a pixel-by-pixel basis in calculating the above information.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	Col. 48	Col. 54	Col. 60	
MOMENT	I	A	J	K	L	M	N	(Input file names)

I - The picture element value for which the moment is calculated.

A - Size of the scanning aperture used, in micrometers.

J and K - The line and column coordinates of the center of the disk with respect to the upper left corner of the original data frame. J and K might each have a negative value. (This assumes that the input frame for MOMENT has been extracted from some larger master frame on which the center of the sun has been located.)

L and M - Line and column coordinates of the upper left corner of the data frame being processed, with respect to the upper left corner of the master data frame.

N - Tag which indicates the aspect corrections desired.

N = 0 - No aspect corrections.

N = 1 - Corrections based on a user supplied table of values.

N = Other - Corrections based on internal table.

If an aspect ratio table is to be supplied by the user (N=1), it is input immediately following the MOMENT operator as follows:

Col. 1

```
TABLE=1.,1.0001,1.0002,1.0003,.....,5.0226$
```

The length of the table must be 120 values.

Subroutines:

AREAC

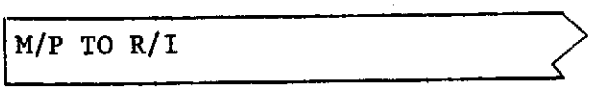
Restrictions:

1) At least two input file names must be specified in parentheses - the feature I.D. file first, followed by the gray level picture file. The feature I.D. file will normally be created by the SUBSET operator.

M/P TO R/I Operator

The M/P TO R/I operator reads a file containing interleaved magnitude/phase data, converts it to real and imaginary data, then writes out the real/imaginary data onto an interleaved file.

Col.
1



Output data type -

Floating point (interleaved)

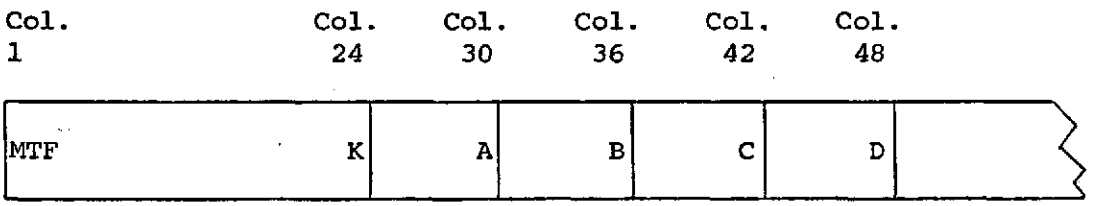
Subroutines:

MPTORI

MTF Operator

The MTF operator generates a rotationally symmetric two-dimensional modular transfer function for general use, having any of several commonly encountered radial profiles. A radial profile may be generated for any of the following shapes:

- Third Order Polynomial
- Delta Function
- Gaussian Distribution
- MTF of a Defocused Perfect Lens
- Quarter Wave, Zero Order Bessel Function



K - Type of function to be generated

K = 1 - Function = $A+BX+CX^2+DX^3$

where X is the distance from the center of the array to a specific picture element.

K = 2 - Function = Delta Function (Δ) where Δ = A where the array line number equals B and where the array column number equals C. If no B or C are specified, Δ will be centered by row and/or column.

K = 3 - Function = Gaussian Distribution

$(B\ e^{-1/2(\frac{3x}{A})^2})$

A = 3δ where δ specifies one standard deviation and the 3δ corresponds to that point on the Gaussian Distribution curve that contains 99% of the area under the curve.

B = The amplitude of the maximum point at the center of the array.

K = 4 - Function = Modulation Transfer Function of a Defocused Perfect Lens T(X)

A = Location of the first zero of the transfer function (for values of $X \geq A$, $T(X) = 0$.)

B = Optical Path Difference which describes the degree of defocusing.
(Normally, $0. \leq B \leq 1.6$.

K = 5 - Function = Quarter Wave, Zero Order Bessel Function
A = Location of the first zero of the function (for $X \geq A$, Function = 0.).

Output data type:

Floating point

Subroutines:

TFGEN

BESJ

LAGRAN

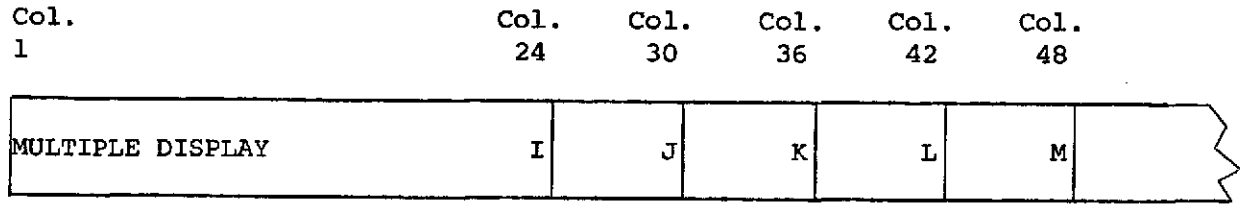
Note: 1) The origin of rotational symmetry will be the center of the array (except when K = 1 and A and/or B are specified).

2) The variable (X) above always refers to the distance (in picture elements) of a pixel from the center of the array.

MULTIPLE DISPLAY Operator

The MULTIPLE DISPLAY operator produces a display tape of 2 or more frames of data. Options available with this operator are;

- Butted pictures.
- Gray scale inversion.
- Image expansion.
- Labelling under each row of pictures.



I - Number of pictures to be put on the output frame. If positive, pictures will be separated by white space. The amount of white space between each picture in a row is determined by the following formula:

SPACE = (1024 - (J*NC))/(J - 1)

where NC is the number of columns in each picture and J is the number of pictures to be placed in each row. If negative, pictures will be butted together. All pictures will be taken from succeeding files of the input tape generated by operator STACK.

J - Number of pictures to be placed in each row across the output frame.

K - Invert gray scale flag

K = 1 - Invert

K ≠ 1 - No inversion

L - Expansion factor. Each picture is expanded by this factor before it is written on the output tape. L must be a positive integer.

M - Total number of cards containing labels.

The format of the label cards is as follows:

Col. 6	Col. 13	Col. 72
N		(label)

N - Row of pictures under which the label is to appear.

The label begins in column 13 and may continue through column 72. If more than 60 characters are required, a continuation card is used. For continuation cards, N is left blank and the label continues in column 13.

Normal tape assignments:

B6 - Input (generated by STACK operator)

A6 - Output

Output data type:

Integer (display format)

Subroutine:

MULDSP

Restrictions:

1) The maximum number of picture columns that may be displayed is 1024.
2) A maximum of 6 lines of labels may be displayed under each row of pictures.
3) A maximum of 102 characters may be displayed in a single line.
4) Horizontal spacing, to center labels under particular pictures, must be accomplished by the user. Each character is 7 pixels broad with a trailing space of 3 pixels; thus each character occupies 10 columns.
5) All pictures on the input tape must be the same size.

NON-SYMMETRICAL PSF Operator

The NON-SYMMETRICAL PSF operator produces a non-symmetric point spread function from a two-dimensional description of a non-symmetric surface (in polar coordinates) and an input profile curve.

Col.
1

```
NON-SYMMETRICAL PSF
```

The non-symmetric surface is input in polar coordinates where a value is specified for each degree. The specified value represents the radial distance from the center of the function measured in picture elements.

```
NSAREA=20.,20.1,20.25,...20.1$
```

The input profile curve is defined by 100 real numbers.

```
CURVE=100.,99.,98.,...0.$
```

The first value after CURVE= corresponds to the amplitude of the 3-D surface over the origin of the base, and the last value in the profile curve corresponds to the amplitude of the surface, 99% of the distance from the origin to the base perimeter defined by NSAREA along a radial from the origin.

Output data type:

Floating point

Subroutine:

NOSFUG

Restrictions:

1) 360 values must be input for the non-symmetrical surface.

2) 100 values must be input for the profile curve.

OUTPUT IMAGE Operator

The OUTPUT IMAGE operator transfers a frame of data from disk to tape in display format. If the image to be output is less than 1024 columns wide, then sufficient zeros are added to make up the difference. This is necessary to view the picture on the Dicomed display tube.

Col.
1

Output data type:

Integer (display format)

Normal tape assignment:

A6 - Output

PAUSE Operator

The PAUSE operator initiates a halt in system operation and prints a message on the on-line printer.

Col.
1

Columns 1 through 72 are printed.

Operation is renewed by pressing START on the operator console.

PRINT Operator

The PRINT operator prints a designated portion of a frame of data.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	Col. 48
PRINT	J	N	M	L	K

J - Print option

- J = 64 - Gray level overprint (integer - off-line)
- J = -1 - Gray level values (integer - off-line)
- J = -2 - Gray level values (integer - on-line)
- J = -3 - Floating point (off-line)
- J = -4 - Floating point (on-line)
- J = 0-63 - Bilevel - blank will be printed for values ≤J, X for those >J (integer - off-line)

N,M - Upper left corner line and column numbers of area to be printed.

L,K - Number of lines and columns in the area to be printed.

Off-line options cause the specified portion of the data to be written on the FORTRAN print tape (B1) instead of on the on-line printer.

Integer values are printed with a maximum of 32 numbers per print line. If the variable (K) is greater than 32, the PRINT operator will print the first 32 columns of all lines specified and then print the next 32 columns in a second pass. As many printing passes as necessary will be made to print the area specified by L and K.

Gray level overprint (J=64) and bilevel print options are handled in the same manner except that a maximum of 132 columns are printed with each pass.

Input data type:

Integer or floating point, as specified by J.

Subroutines:

HRDCPY

PSF GENERATOR Operator

The PSF GENERATOR generates an NxN point spread function.

Col. 1	Col. 24
PSF GENERATOR	N

N - Size of the PSF.

The profile of a PSF is input as follows, where the number of data values is equal to $\frac{N+1}{2}$ truncated:

Col.
1

```
CURVE = 63.,30.,10.,5.$
```

Output data type:

Floating point

Subroutines:

PSFGEN

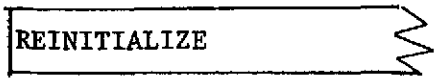
Restrictions:

1) The size of the PSF generated (N) should be no greater than 100.

REINITIALIZE Operator

The REINITIALIZE operator reinitializes the disk file directory and should be used between unrelated back-to-back runs.

Col.
1



REPEAT Operator

The REPEAT operator provides the user with the capability to repeat a sequence of IDAPS operators.

Col. 1	Col. 24
REPEAT	J

J - The number of times the sequence of operators is to be repeated.

The REPEAT operator is followed by the operator cards to be repeated. These operator cards may contain absolute or variable parameters. The series of operator cards is terminated by either a DATA or an END operator. If only absolute parameters are used, the END operator is used. If there are variable parameters in the operator series, the DATA card is used, followed by the variable values in the following format:

Col. 6	Col. 12	Col. 18	Col. 24	Col. . . . 30	Col. 72
K	V_1	V_2	V_3	V_4	V_{11}

K - Variable name (6 or less alphabetic characters)

V_i - Variable value for loop i where i goes from 1 to J

Variable parameters are specified on the operator cards by alphabetic names For an example, see Figure 2.

Method:

All operator cards within the repeat loop are transferred to core, the variable values are filled in for each pass and the series of operators is generated on tape B7 (13). Operators are read from B7 instead of from the card reader for as long as the loop is being executed. When the loop is completed, operators are again read from the card reader.

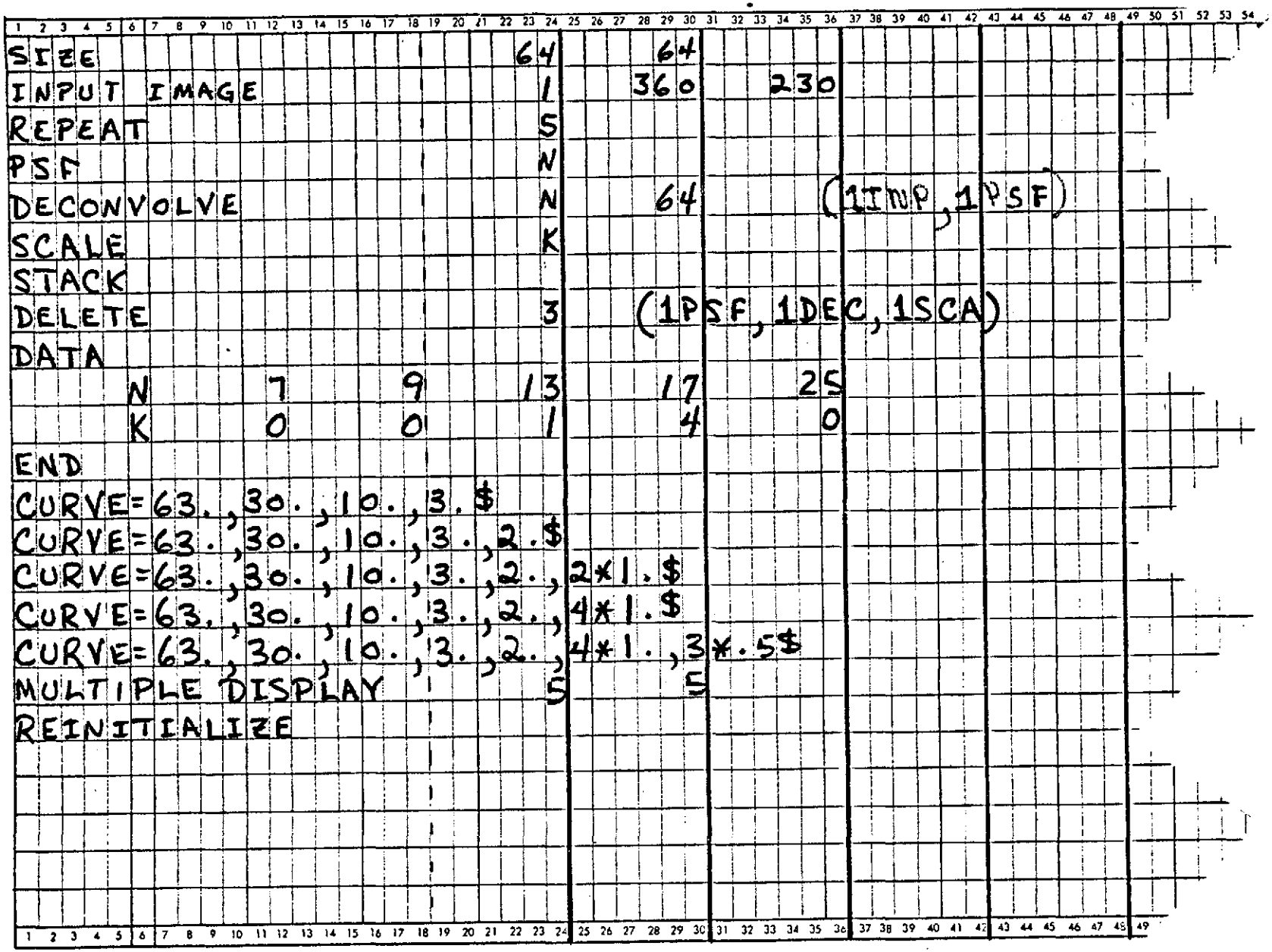


Figure 2 - Example of Use of REPEAT Operator

Restrictions:

1) If there are variables in the repeat sequence, J may not be greater than 11.
2) A maximum of 39 variable names may be used.
3) A maximum of 40 operators may be listed in the sequence.
4) REINITIALIZE may not be used within the loop.
5) Data cards for the tables required by the following operators must be placed after the END operator. There must be 1 table for each pass through the loop.

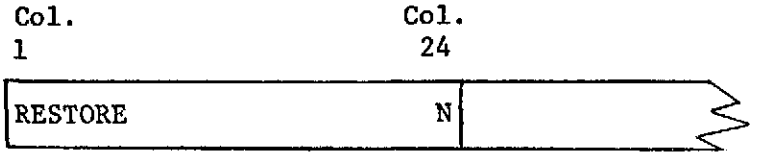
    ALTER
    DEPENDENT ALTER
    FEATHER
    ISOGRAM
    PSF GENERATOR
    MOMENT
    NON-SYMMETRIC PSF
    FUNCTION GENERATOR
    FILTER
    FIELD CORRECTION
    AREA

    If more than one of these operators is used within the loop, the data cards must be arranged in the order in which they are used.

6) No nesting of REPEATs is permitted.
7) Variable file name parameters are not permitted. Therefore, when file names are specified that have been created within the REPEAT loop, a DELETE operator should be inserted before the END card to clear the file directory of the files created by the previous pass through the loop (See preceeding example.)

RESTORE Operator

The RESTORE operator renews the disk file directory by retrieving the most recent copy of the directory from disk or tape.



N ≠ 1 - File directory restored from disk.

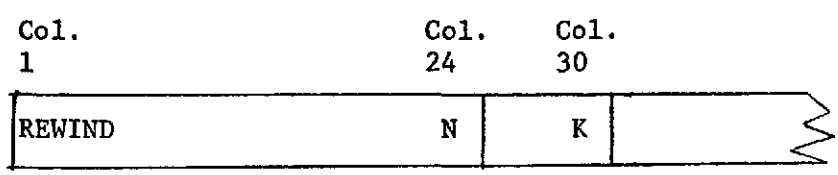
N = 1 - File directory restored from tape (Unit A6).

Subroutine:

RESTOR

REWIND Operator

The REWIND operator rewinds and optionally unloads a tape.



N - Tape logical unit number

K - Flag to unload the tape

K = 1 - Unload

K = Other - Do not unload

R/I TO M/P Operator

The R/I TO M/P operator reads a file containing interleaved real/imaginary data, converts it to magnitude and phase data, then writes out the M/P data onto an interleaved file.

Col.
1

Output data type:

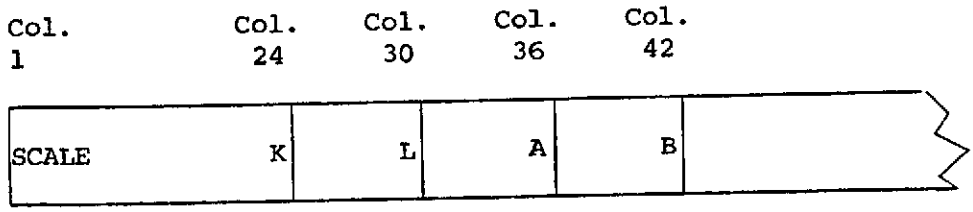
Floating point (interleaved)

Subroutines:

RITOMP

SCALE Operator

The SCALE operator scales floating point data between 0 and 63.



K - Type of scaling
- K = 1 - Logrithmic
- K = 2 - Square root
- K = 3 - Cube root
- K = 4 - Square
- K = Other - Linear

L - Clipping flag
- L = 1 - Clip outside of A and B
- L = Other - No clipping

A - Lower clipping level. All input values below A will be set to 0.

B - Upper clipping level. All input values above B will be set to 63.

Output data type:

Floating point

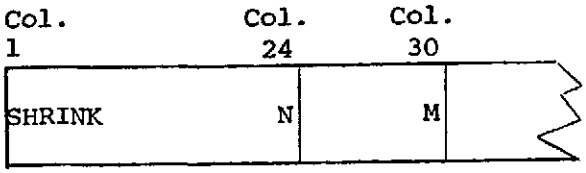
Subroutine:

SCAL

Note: The SCALE operator first examines the input file to determine the maximum and minimum values contained therein and then scales the contents of the file between those limits. If the clipping option is used and if the range of values exceeds either the minimum or maximum limit specified, the clipping limit will determine the range over which the scaling occurs.

SHRINK Operator

The SHRINK Operator reduces the size of a picture by an integer shrink factor.



N - Integer shrink factor (resulting picture is 1/Nth as large as the original.)

M - Shrinkage method

M = 1 - every N'th point

M ≠ 1 - average of consecutive N x N arrays.

Output data type:

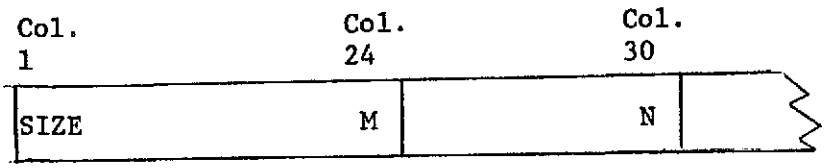
Integer

Subroutine:

SHRINK

SIZE Operator

The SIZE operator specifies the size of the input frame to be processed by the succeeding operators. A new size specification must be made only when there is a change in the size of the frame.



M - Number of lines per frame.

N - Number of columns per frame.

SLICE Operator

The SLICE operator produces a line graph of gray values found between two points.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42
SLICE	I	J	K	L

I - Line number of point 1

J - Column number of point 1

K - Line number of point 2

L - Column number of point 2

Subroutines:

SLICE

Restrictions:

1) Floating point files should be SCALE'd prior to being SLICE'd.

C2

SMOOTH Operator

The SMOOTH operator spatially integrates each pixel of a frame of data by averaging its eight neighboring pixels and adjusting the center pixel by some factor to bring it closer to the average of its neighbors.

$$\text{IF} \quad \left| Q - \frac{\sum_{n=1}^{8} P_n}{8} \right| > L \quad \text{then } Q = Q + Y \left[\frac{\sum_{n=1}^{8} P_n}{8} - Q \right]$$

$$\text{IF} \quad \left| Q - \frac{\sum_{n=1}^{8}}{8} \right| \leq L \quad \text{then } Q = Q$$

Col. 1	Col. 24	Col. 30	
SMOOTH	L	Y	

L - Limit by which the center pixel is allowed to deviate from the average of its neighbors without adjustment

Y - Factor by which the center pixel is adjusted if Q is greater than L

Output data type:

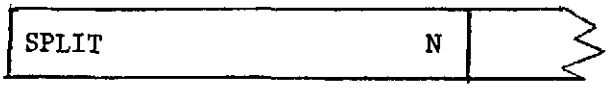
Integer or floating point (same as input)

Suborutine:

SPINT

SPLIT Operator

The SPLIT operator extracts the real, imaginary, magnitude or phase terms from an interleaved file.



N ≠ 1 - Split out real or magnitude values

N = 1 - Split out imaginary or phase values

Output data type:

Floating point

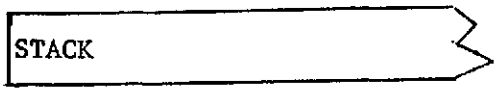
Subroutines:

SPLT

STACK Operator

The STACK operator stacks a frame of data on tape B6 (logical unit 11).

Col.
1



Output data type:

Integer

Subroutines:

STKPIC

Restrictions:

1) When the output of STACK is used as input to MULTIPLE DISPLAY, all stacked images must be the same size.
2) No end of file marks separate the stacked images.

STOP Operator

The STOP operator terminates the run sequence and returns control to IBSYS.

Col.
1

SUBSET Operator

The SUBSET operator identifies all pixels within a subset which are related to each other by virtue of similar gray levels and by their eight-neighbor connectivity. Every pixel within a subset is identified by a distinct floating point subset number. In this way an output array of floating point numbers is produced where all array locations with identical values belong to a common subset. This operator provides the ability to specify upper and lower gray level boundaries for subset identification and to limit subset I.D. assignment to subsets with more than a certain minimum number of pixels. Subset I.D.'s are assigned in order of decreasing size, so that the largest subset is always subset number 1. If M and N are specified, only the subset within which the (M,N) resides is set to 63; the background is set to zero.

Col. 1	Col. 24	Col. 30	Col. 36	Col. 42	Col. 48	Col. 54
SUBSET	I	J	K	L	M	N

I - Lower limit. Only pixels greater than or equal to I are included in the subset identification.

J - Upper limit. Only pixels less than or equal to J are included in the subset identification.

K - Size limit. Subsets having fewer than K pixels are not included in the subset identification.

L - Complement flag.

L = 1 - Complement input gray values before processing

L ≠ 1 - No complement

M - Line coordinate of point within a subset

N - Column coordinate of point within a subset

Output data type:

Floating point

Subroutines:

SEGMNT

Note: Single, isolated points which fall within the limits of I and J are never considered as subsets by this operator.

TRANSPOSE Operator

The TRANSPOSE operator transposes a frame of data about the major diagonal, replacing lines by columns, so that the nth column becomes the nth line. For example, an F would appear as [F] .

Col.
1

Output data type:

Integer or floating point (same as input)

Subroutines:

TRNPS

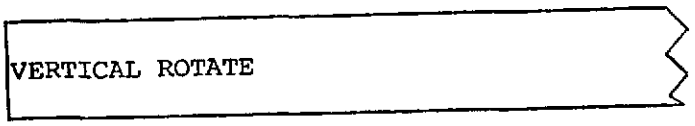
TRANS

DRIVTP

VERTICAL ROTATE Operator

The VERTICAL ROTATE operator flips a frame of data about a central vertical axis so that column 1 becomes column n, column 2 becomes column (n-1), etc. For example, an F would appear as ⅂ .

Col.
1



Output data type:

Integer or floating point (same as input)

Subroutines:

TRNPS

DRIVTP

FLIP

APPENDIX A - OPERATOR TIMING
(in seconds)

OPERATOR	64 x 64	128 x 128	256 x 256	512 x 512
+90 DEGREE ROTATE	5.1	10.5	33.5	147.6
180 DEGREE ROTATE	5.1	5.7	13.1	41.0
-90 DEGREE ROTATE	5.1	9.7	30.1	134.9
ALTER	3.6	5.4	12.2	37.5
AND	6.6	7.7	25.1	74.6
AVERAGE	4.8	8.5	26.8	101.2
BAR CHART	5.2	5.2	6.5	17.2
CENTER TRANSFORM	6.3	16.7	64.1	274.0
CONVOLVE	38.7	159.7	767.6	---
CORRELATE	41.2	171.5	858.2	---
DECONVOLVE	43.5	178.0	890.8	---
DEPENDENT ALTER	6.6	13.0	37.0	132.5
DUMP FILE	4.1	6.6	19.9	89.5
EXPAND	4.9	9.3	27.0	113.6
EXTRACT	4.9	5.0	6.9	20.0
FEATHER	4.0	6.9	17.2	56.0
FFT	15.0	56.2	266.7	1541.0
FILTER	8.0	22.2	81.4	332.8
FIX	5.9	8.0	22.6	97.7
FLOAT	6.0	8.0	22.3	94.0
FOURIER FILTER	18.3	77.2	408.6	2071.8
FUNCTION GENERATOR	9.2	34.2	178.1	1102.3
HISTOGRAM	67.4	71.2	85.4	145.2
HORIZONTAL ROTATE	5.1	5.1	10.6	27.4
IFFT	15.9	59.6	281.8	---
INCLUSIVE OR	6.6	7.7	24.3	97.0
INPUT IMAGE	3.7	5.7	9.5	26.8
ISOGRAM	6.0	13.5	42.8	157.4
LOAD FILE	4.7	9.1	28.6	118.8
MATH	6.0	10.6	38.2	143.9
MERGE	6.7	17.8	124.4	---

OPERATOR	64 x 64	128 x 128	256 x 256	512 x 512
MINOR TRANSPOSE	5.1	10.5	33.6	148.3
M/P TO R/I	8.2	26.7	108.0	---
NON-SYMMETRIC PSF	16.9	42.9	146.4	573.6
OUTPUT IMAGE	3.3	4.4	8.8	26.1
PRINT	8.5	23.9	81.9	337.7
R/I TO M/P	8.2	26.0	107.9	---
SCALE	8.5	20.9	83.4	320.8
SLICE	33.3	62.3	121.3	241.9
SMOOTH	4.9	6.1	16.4	57.9
SPLIT	5.7	11.9	38.7	---
STACK	3.3	4.1	10.7	33.0
TRANSPOSE	5.1	9.8	30.2	136.1
VERTICAL ROTATE	5.1	5.6	13.1	44.3

APPENDIX B - OPERATOR SUMMARY

OPERATOR	NUMBER OF PARAMETERS		DATA CARDS	NUMBER OF DISK FILES			TAPES REQUIRED
	Required	Optional		INPUT	SCRATCH	OUTPUT	
+90 DEGREE ROTATE	0	0		1	5	1	
180 DEGREE ROTATE	0	0		1	5	1	
-90 DEGREE ROTATE	0	0		1	5	1	
ALTER	0	0	Yes	1	0	1	
AND	0	0		2	0	1	
AREA	6	1	Optional	1	0	0	
AVERAGE	1	0		1 - 5	0	1	
BAR CHART	1	0		0	0	1	
CENTER TRANSFORM	0	0		1	0	1	
COMMENT	0	0		0	0	0	
CONVOLVE	2	1		2	4	1	
CORRELATE	1	0		2	4	1	
DECONVOLVE	2	3		2	4	1	
DELETE FILES	1	0		0	0	0	
DEPENDENT ALTER	1	0	Yes	1	0	1	
DISTANCE	4	0		1	0	0	
DUMP FILE	1	0		1	0	0	1*
EXPAND	5	0		1	0	1	
EXTRACT	4	0		1	0	1	
FEATHER	1	0	Yes	1	0	1	
FFT	1	1		1	2	1	

APPENDIX B - OPERATOR SUMMARY

OPERATOR	NUMBER OF PARAMETERS		DATA CARDS	NUMBER OF DISK FILES			TAPES REQUIRED
	Required	Optional		INPUT	SCRATCH	OUTPUT	
FIELD CORRECTION	1	0	Yes	1	0	1	B7
FILTER	0	0	Yes	1	0	1	
FIX	0	0		1	0	1	
FLOAT	0	0		1	0	1	
FOURIER FILTER	0	1		2	4	1	
FRAME	0	8	Yes	1	0	0	A6
FUNCTION GENERATOR	0	1	Yes	0	0	1	
HISTOGRAM	0	0		1	0	0	
HORIZONTAL ROTATE	0	0		1	5	1	
IFFT	0	0		1	2	1	
INCLUSIVE OR	0	0		2	0	1	
INPUT IMAGE	3	0		0	0	1	A5
INSERT	4	1		2	0	1	
ISOGRAM	0	1	Yes	1	0	1	
LABEL	3	0	Yes	0	0	0	2*
LOAD FILE	2	0		0	0	1	1*
MATH	1	1		1 - 2	0	1	
MERGE	0	0		2	0	1	
MFT	1	4		0	0	1	
MINOR TRANSPOSE	0	0		1	5	1	
MOMENT	6	1	Optional	2	0	0	
M/P TO R/I	0	0		1	0	1	
MULTIPLE DISPLAY	2	3	Optional	0	1	0	B6, A6

APPENDIX B - OPERATOR SUMMARY

OPERATOR	NUMBER OF PARAMETERS		DATA CARDS	NUMBER OF DISK FILES			TAPES REQUIRED
	Required	Optional		INPUT	SCRATCH	OUTPUT	
NON-SYMMETRICAL PSF	0	0	Yes	0	0	1	
OUTPUT IMAGE	0	0		1	0	0	A6
PAUSE	0	0		0	0	0	
PRINT	5	0		1	0	0	
PSF GENERATOR	1	0	Yes	0	0	1	
REINITIALIZE	0	0		0	0	0	
REPEAT	1	0	Optional	0	0	0	B7
RESTORE	0	1		0	0	0	A6 Opt.
REWIND	1	1		0	0	0	1*
R/I TO M/P	0	0		1	0	1	
SCALE	0	4		1	1	1	
SHRINK	1	1		1	0	1	
SIZE	2	0		0	0	0	
SLICE	4	0		1	0	0	
SMOOTH	2	0		1	0	1	
SPLIT	0	1		1	0	1	
STACK	0	0		1	0	0	B6
STOP	0	0		0	0	0	
SUBSET	3	3		1	2	1	
TRANSPOSE	0	0		1	5	1	
VERTICAL ROTATE	0	0		1	5	1	

* OPTIONAL TAPE UNIT - A5, A6 OR B6